FOUR YEARS OF ABSOLUTELY CALIBRATED HYPERSPECTRAL DATA FROM THE ATMOSPHERIC INFARED SOUNDER (AIRS) ON THE EOS AQUA

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Outline

A quick overview of AIRS

What absolute calibration accuracy
and stability are required for climate applications?

Validating radiance accuracy and stability:
Results from four years od AIRS data

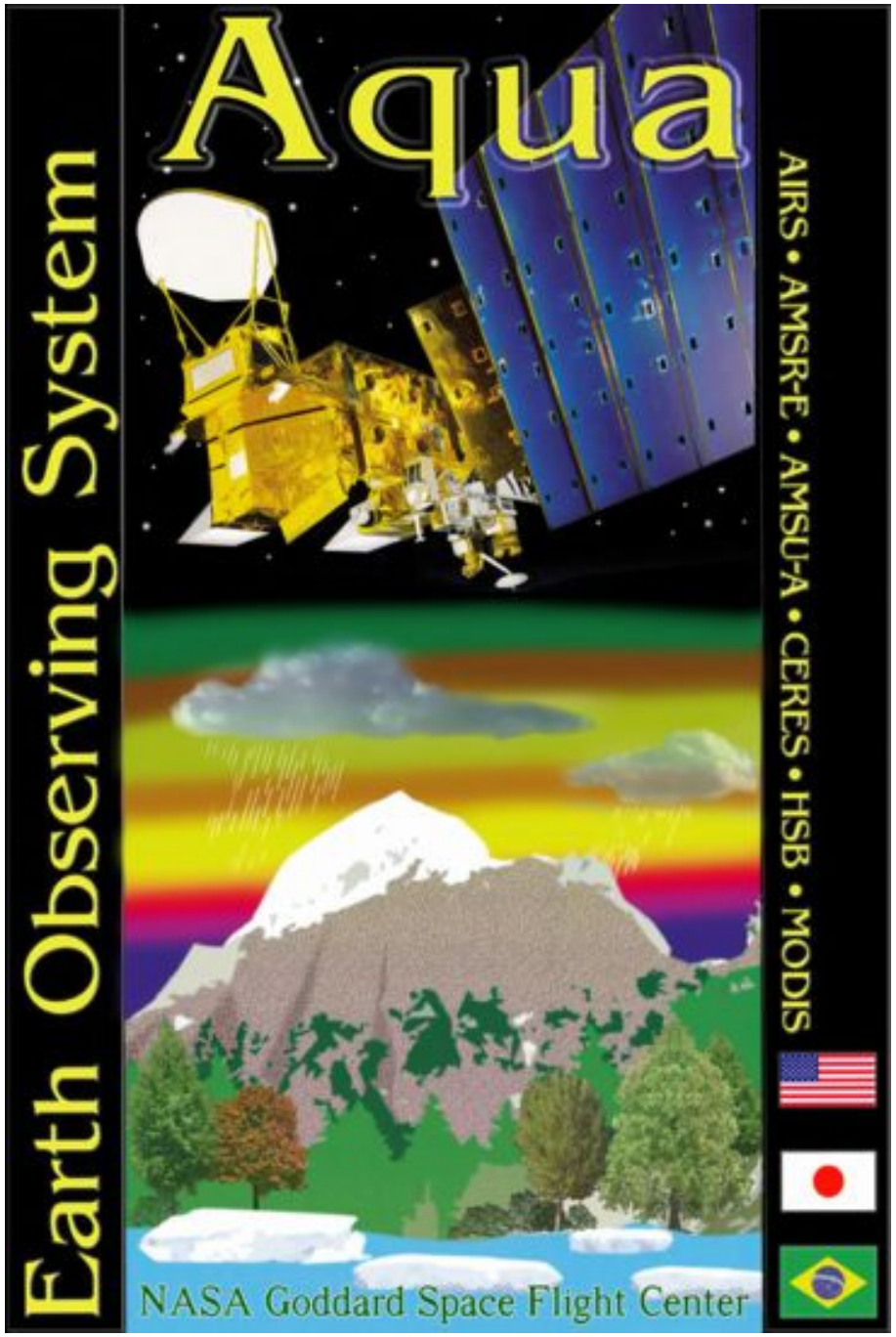
Conclusions

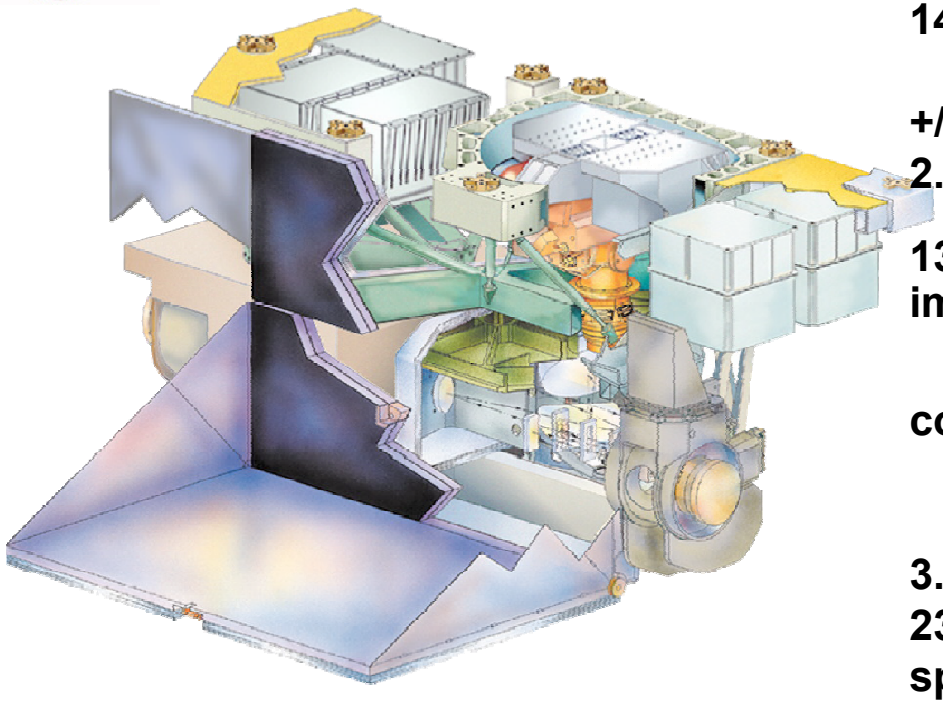
AIRS/AMSU/ HSB

Spacecraft:	**EOS Aqua**
Instruments:	**AIRS, AMSU, HSB, MODIS, CERES, AMSR-E**
Launch Date:	**May 4, 2002**
Launch Vehicle:	**Boeing Delta II Intermediate ELV**
Mission Life:	**5 years**
Team Leader:	**Moustafa Chahine**

AIRS Project Objectives

1. **Support Weather Forecasting**
2. **Climate Research**
3. **Atmospheric Composition and Processes**





AIRS on EOS Aqua
705 km altitude polar orbit
14 orbits per day

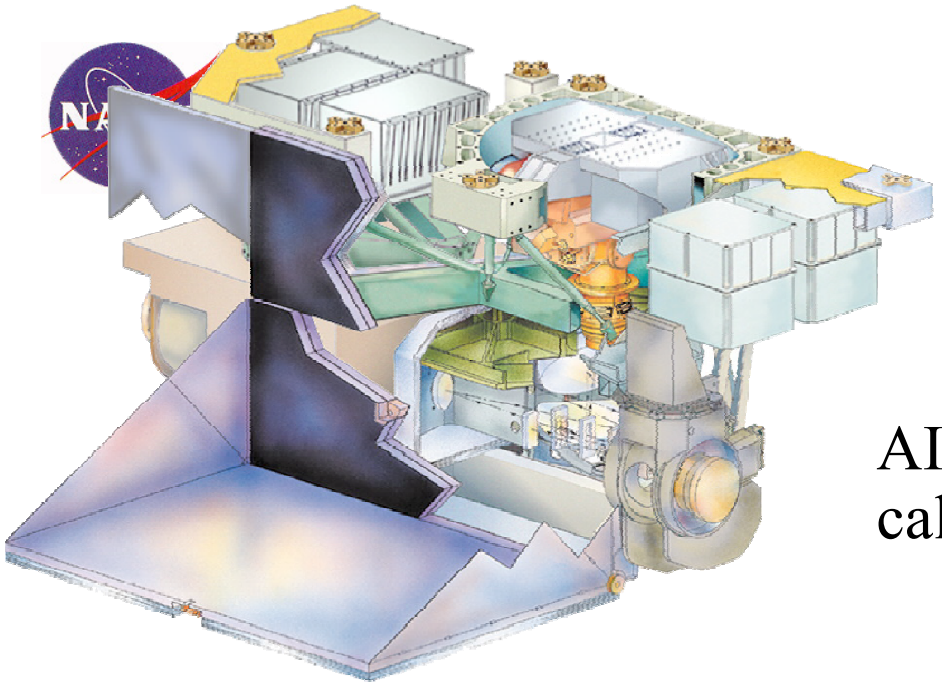
+/- 50 degree cross-track scanning
2.9 million spectra per day

13.5 km IR FOV at nadir
imaging with 98% overlap

cooled grating array spectrometer
58K detectors

3.7 – 15.4 microns
2378 spectral channels
spectral resolution 1200
spectral sampling 2400 (Nyquist)

NeDT= 50%tile better than 0.2K at 250K



AIRS was designed, built and calibrated for climate quality data

Designed to achieve better than 3% absolute radiance accuracy between 200K and 360 K and 3.7 – 15.4 microns for 5 years.

Full aperture wedge cavity blackbody at 308 K (+/-10 mK)

Spectrometer optical bench cooled to 156 K +/-10 mK

One blackbody view and four space views every 2.67 seconds

Prelaunch calibration with NIST secondary standard between 220 K and 340 K, at 6 scan angles and at three spectrometer temperatures.

The expectation from AIRS were achieved

Chahine et al. 2006 BA

12 hour forecast impact in 5 days achieved in both hemispheres

LeMarshal et al. 2006 BAMS 15 July

RAOB equivalent accuracy achieved relative to the RAOB matchups at mandatory levels

Divacarla et al. 2006 JGR

The expectation from AIRS were achieved

Better than 0.2 K absolute accuracy

Tobin et al. 2006 JGR

Stability better than 16 mK/year

Aumann et al . 2006 JGR

The first four years of data from AIRS already constitute the largest hyperspectral infrared global data set available for climate research

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What absolute calibration accuracy and stability are required for climate applications?

The accuracy of the measurements has to be better than the changes due to global warming

Warming at the surface is happening at 10 mK/year
Warming of the atmosphere is assumed to happen at 10 mK/year
The stratosphere appears to be cooling at about the same rate.

A 100 mK absolute calibration shift between sounders is the equivalent of 10 years of global warming

What absolute calibration accuracy and stability are required for climate applications?

Climate quality measurements have to be

NIST traceabble

accurate at the better than 50 mK level

stable to better than 5 mK/year
for a significant fraction of 20 years

transferable to different instruments.

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Validating of radiance accuracy and stability

For the validation of calibration accuracy and stability we have to

find a reliable NIST traceable reference source

deal with clouds

Validating of radiance accuracy and stability

We deal with clouds by applying a strict cloud filter which uses spatial coherence and spectra filtering.
Details in Aumann et al . 2004 Denver SPIE

The NIST traceable reference source are the drifting buoy surface temperature measurements in the tropical oceans

The ARS sst measurements use window channels at 2616 and 1231 cm-1

Details in Aumann et al. 2006 JGR paper.

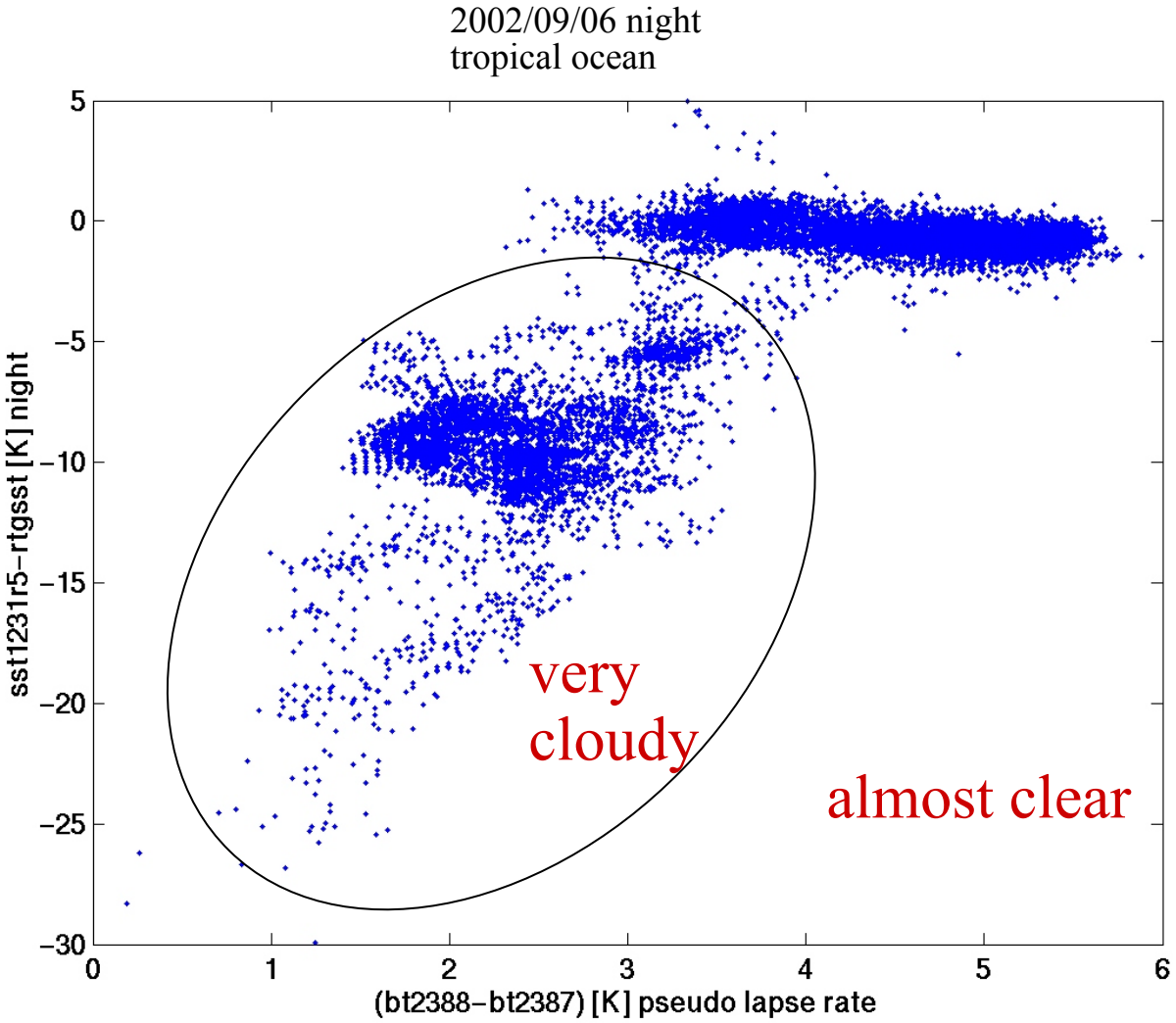
For the validation of calibration accuracy and stability we have to deal with clouds

Measurements with 50 mK absolute accuracy are not useful for climate if they are biased by clouds.

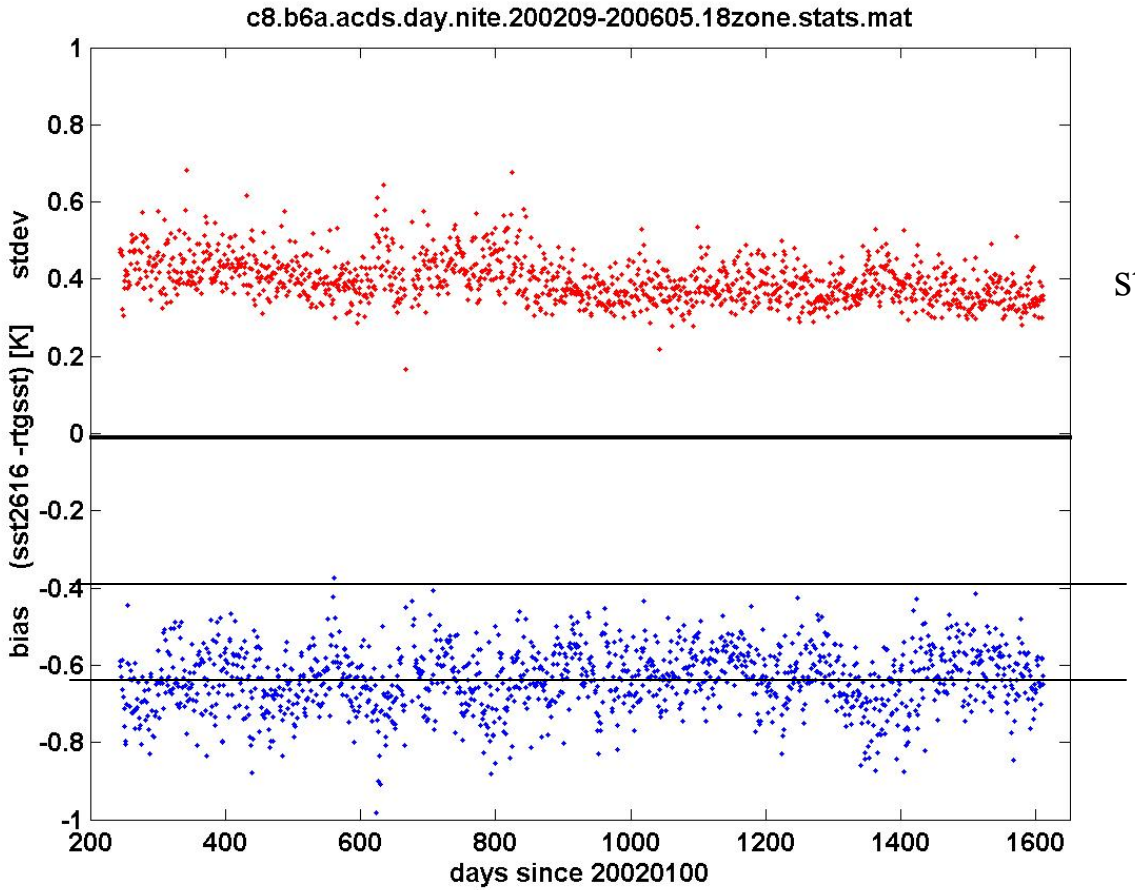
Cloud effects are easy to see when looking at the sea surface during the day. Night is much harder.

Residual cloud effects may show up in mid-tropospheric water vapor and lapse rate measurements

All points shown below passed a strict spatial coherence test
A large number of stratus clouds passed the test



4 years of night-time comparisons of 2616 cm-1 with the RTGSST are within 200 mK of the expected value



stdev is only 0.4 K

Expected bias

Observed bias

The blue dots are the median result from each day
The red dots are the standard deviation of the 6000 clear spectra each day

H. H. Aumann JPL

4 years of night-time comparisons of 2616 cm-1 with the RTGSST have a 200 mK cold bias using the NIST traceable calibration

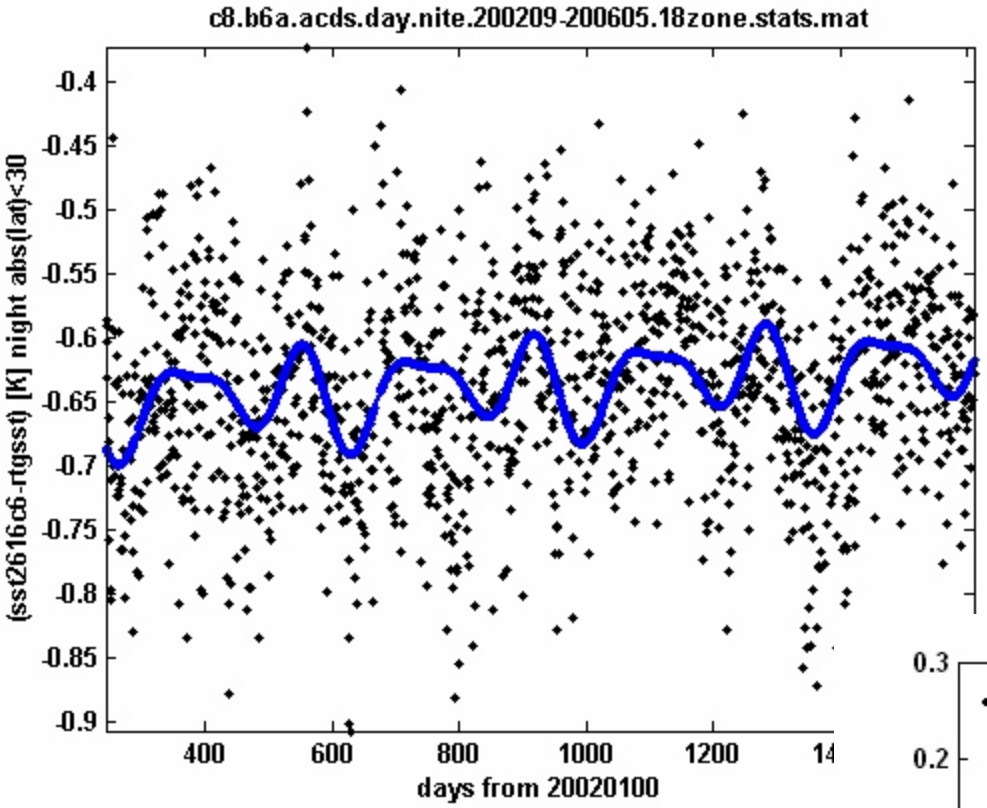
The same bias shows up day and night at 2616 cm-1 and at 1231 cm-1

In Aumann et al. 2006 we show that the cold bias is due to residual cloud contamination.

This instrument and cloud filter specific cloud contamination

exceeds the absolute calibration accuracy

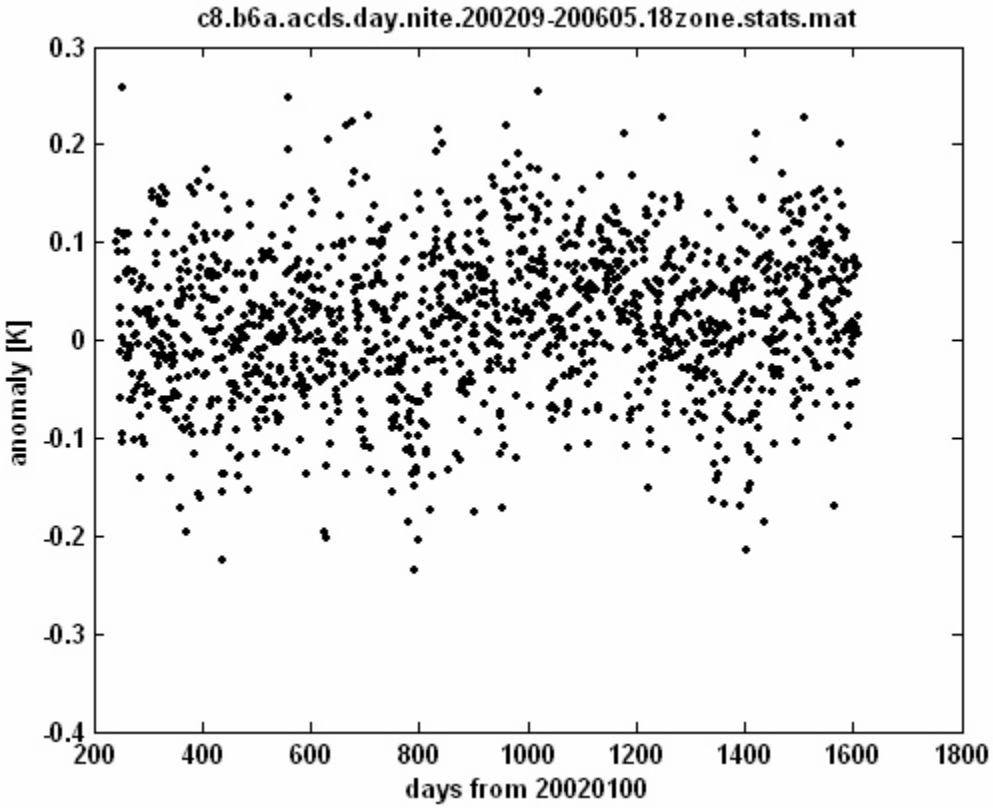
may create trend artifacts

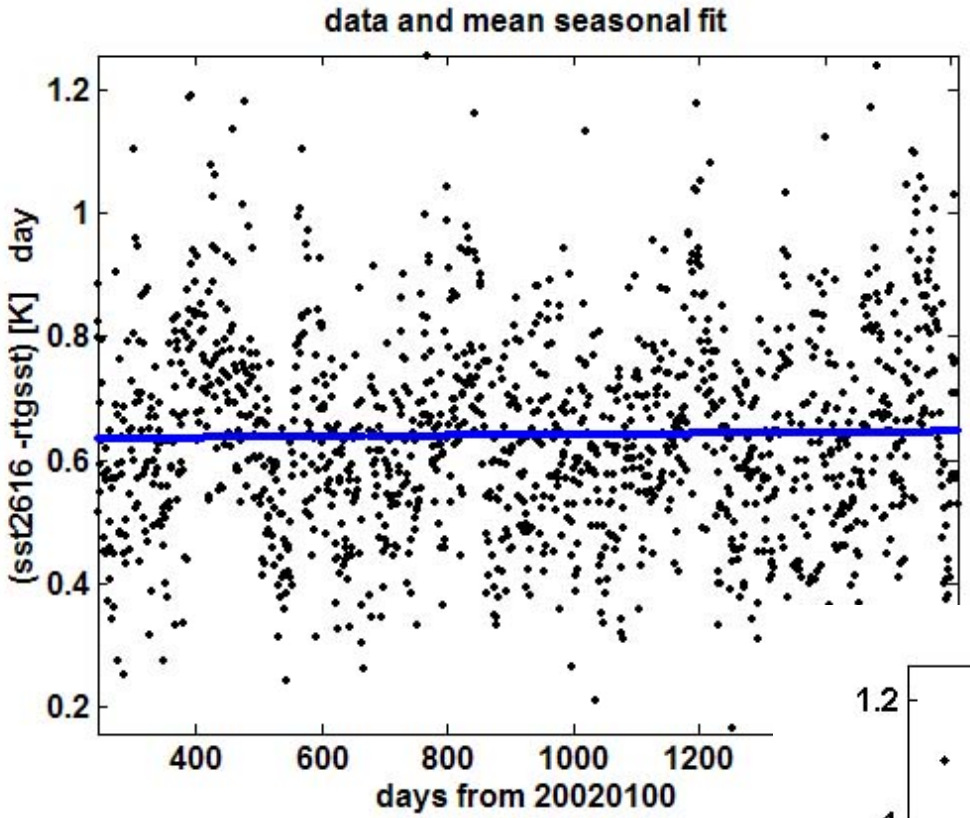


The anomaly trend for
sst2616-rtgsst
= 8 +/- 2 mK/year
for 4 years of night time data

The black dots are the median from each day
The blue trace is the four seasonal mean

There is a small trend
at night for sst2616-rtgsst



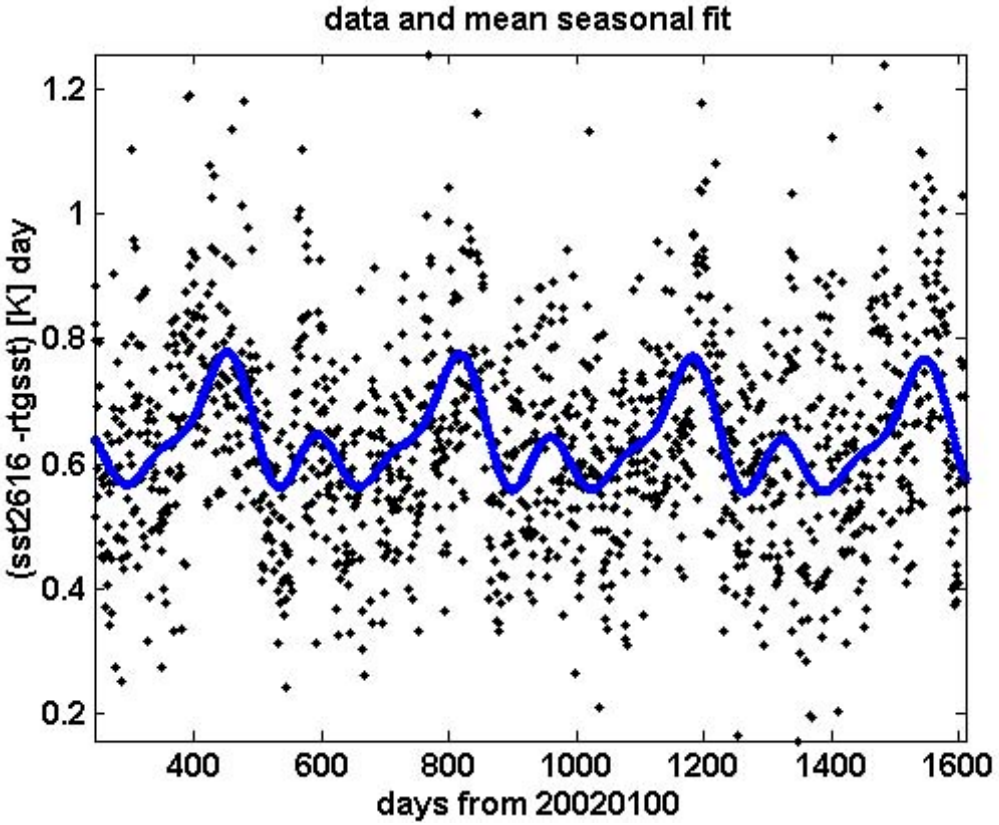


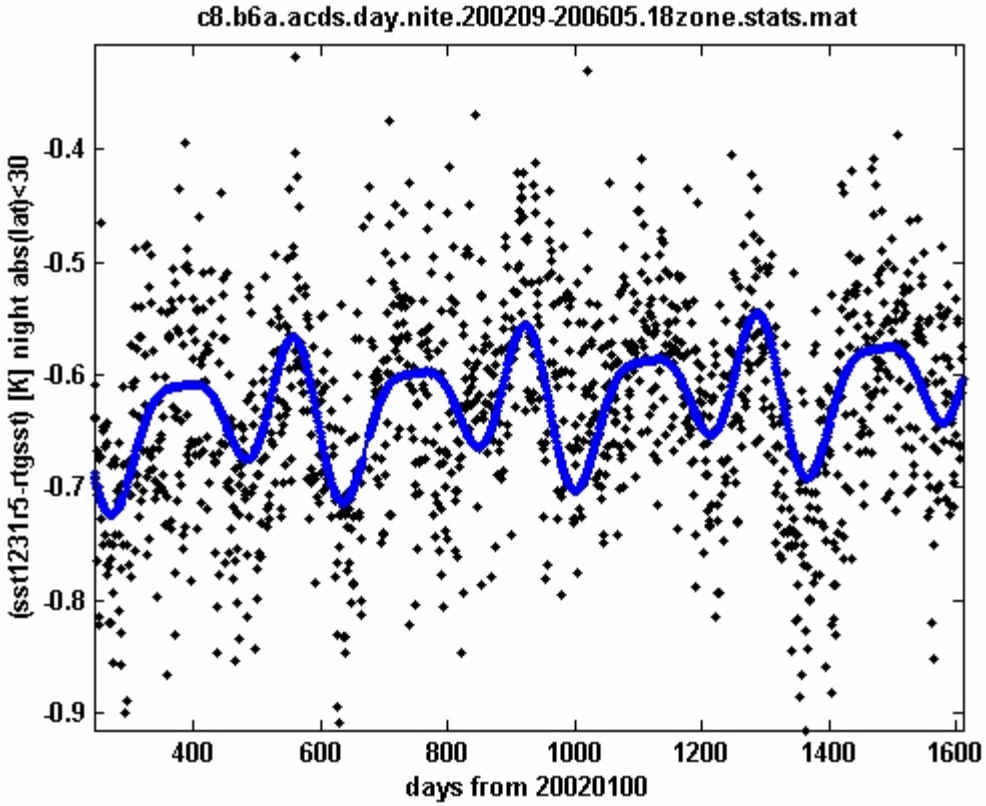
Direct trend (left)
sst2616-rtgsst = 3 +/- 4 mK/year

Anomaly trend (below)
Sst2616-rtgsst=-4 +/-4 mK/year

The black dots are the median from each da
The blue trace is the four seasonal mean

There is no significant trend in sst2616 during the day

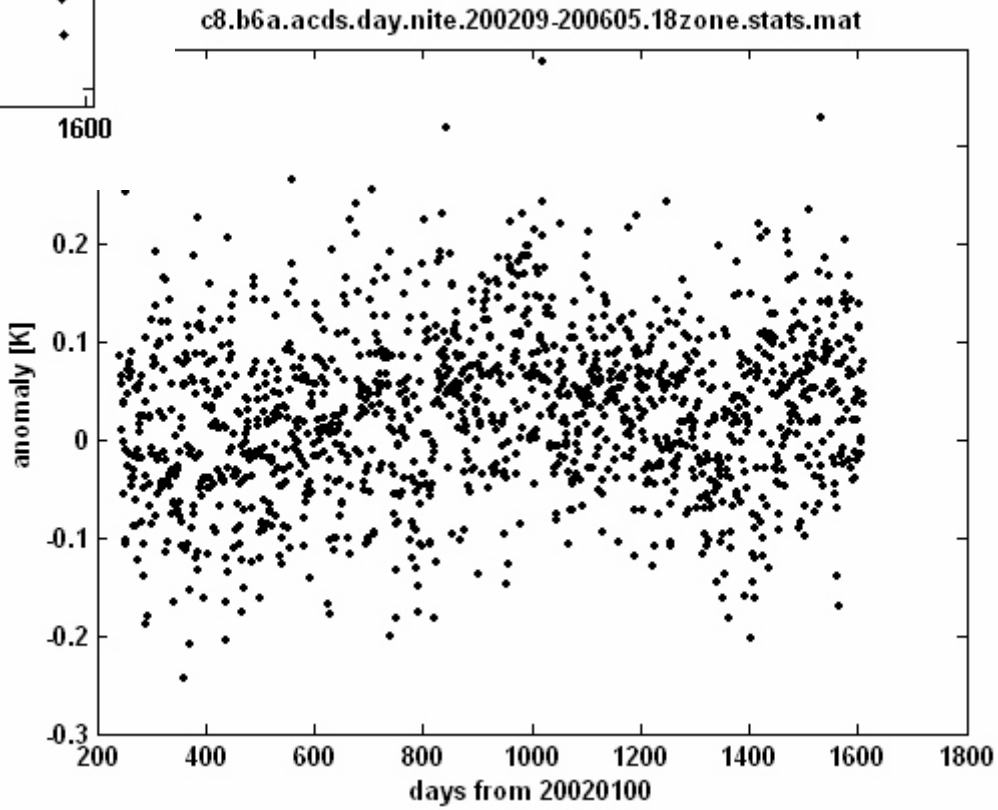


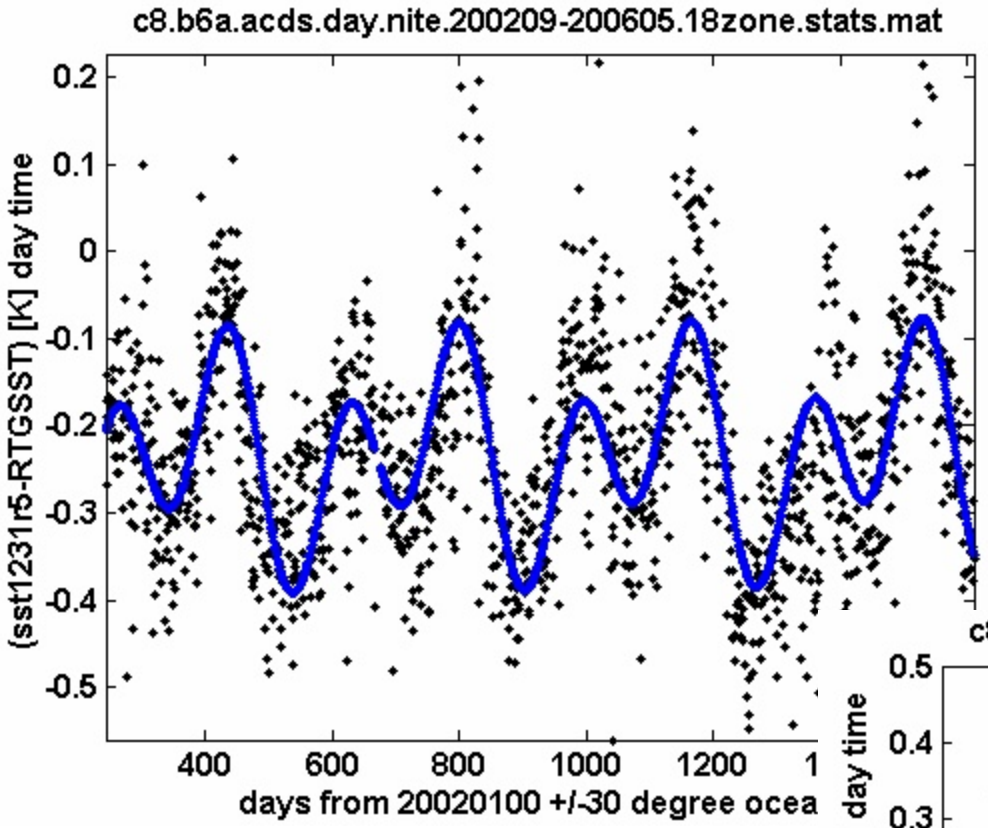


The anomaly trend for
sst1231-rtgsst
= 11 +/- 2 mK/year
for 4 years of night time data

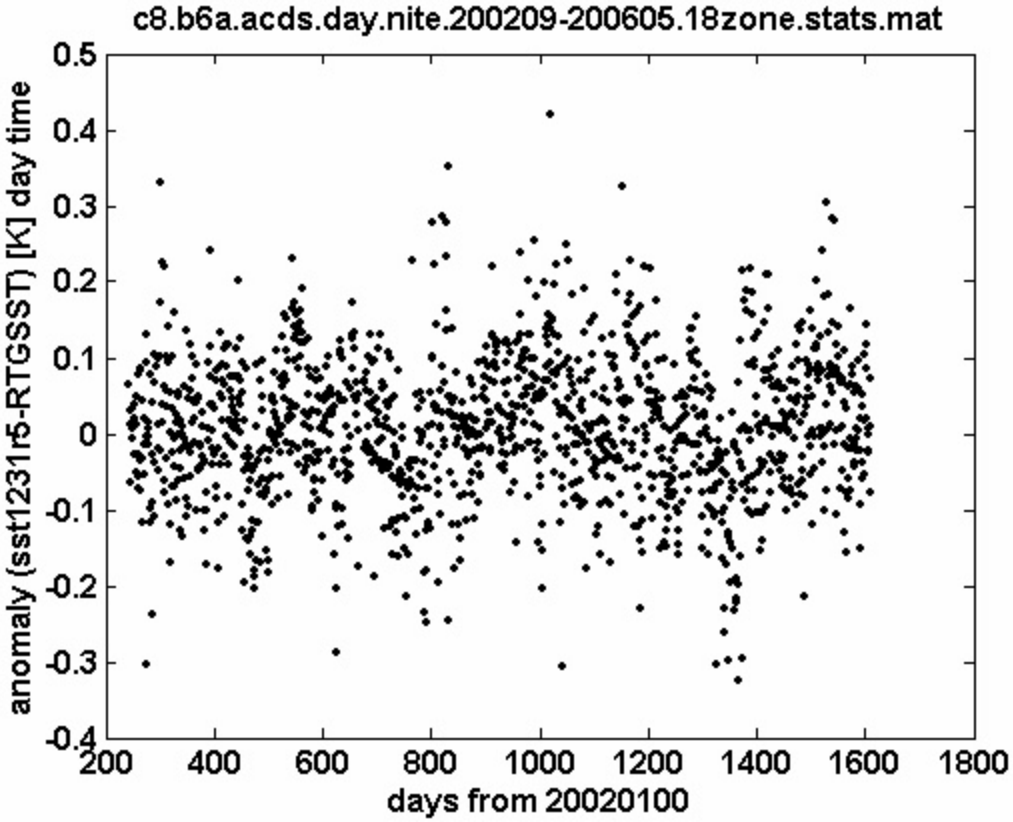
The black dots are the median from each day
The blue trace is the four seasonal mean

There is a small trend
in sst1231 a night





The anomaly trend for
sst1231-rtgsst
= 3 +/- 2 mK/year
for 4 years of day time data



The black dots are the median from each day
The blue trace is the four seasonal mean

There is no significant trend
in sst1231 during the day

The AIRS data are extremely stable

1231 cm-1 channel stability night +11 +/- 2 mK/year
day + 3 +/- 2 mK/year

2616 cm-1 channel stability night + 8 +/- 2 mK/year
day - 4 +/- 4 mK/year

There appears to be a significant night trend.
The cold bias is decreasing at night

It is difficult to argue that this is an instrument trend.

The cold bias is due to residual cloud contamination.
The inter-annual variability of the cloud pattern
shows up as a trend in the bias.

The validation uses three steps:

1. Find spectra which are cloud-free at the better than 200 mK level. About 1% yield

2. Tie the clear radiance via the best window channels to a NIST traceable source at the surface. Use night data to avoid solar surface heating

3. Extend the verification to all channels via (obs-calc)

The verification to all channels via (obs-calc) using ECMWF confirms stability of all channels

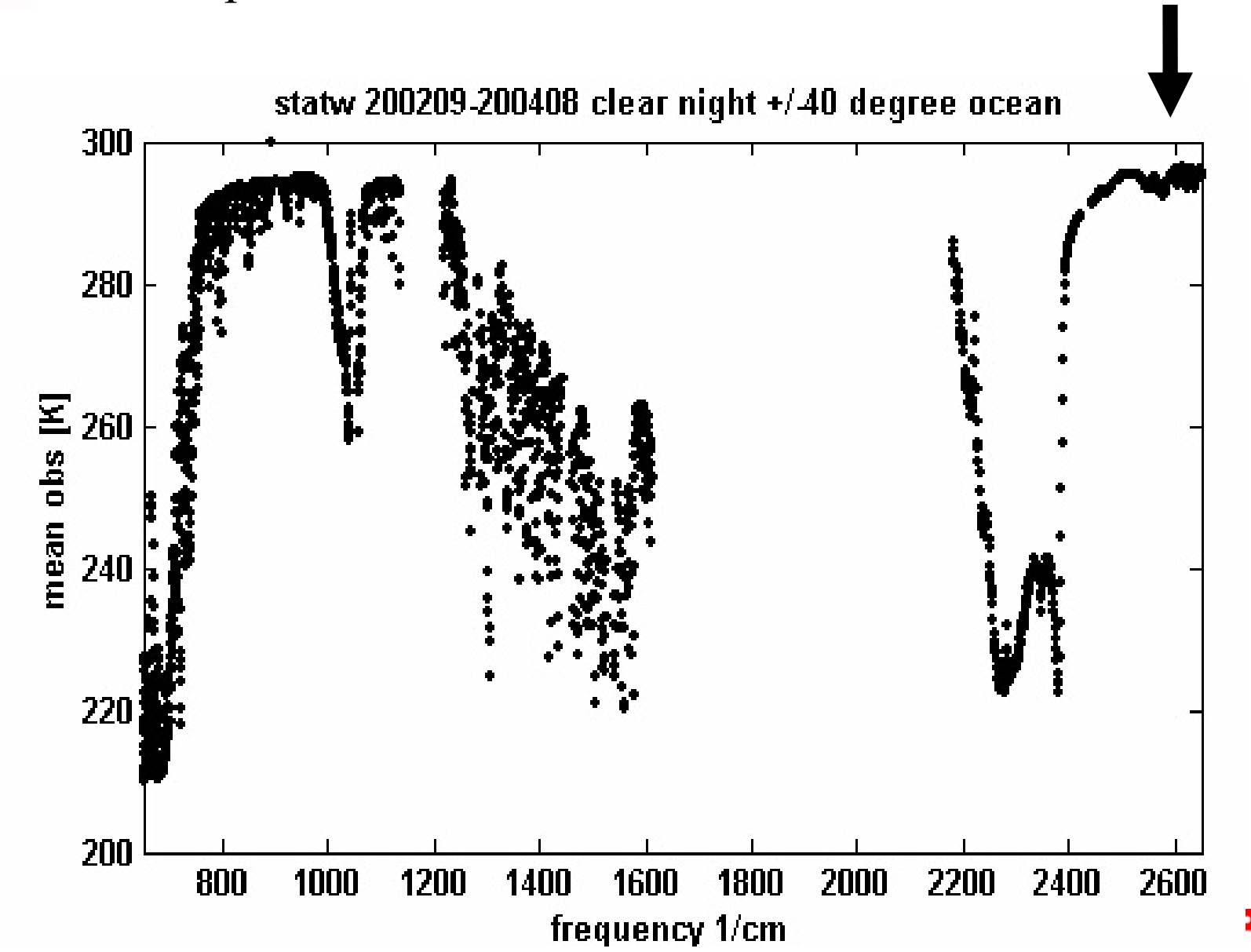
We use the ECMWF T(p) q(p) for calc, except
replace TSurf by the SST at 2616 cm-1 and
normalize the total water using bt2616-bt2607

Use the January 2003 AIRS RTA for calc for
clear night ocean +/-40 degree latitude

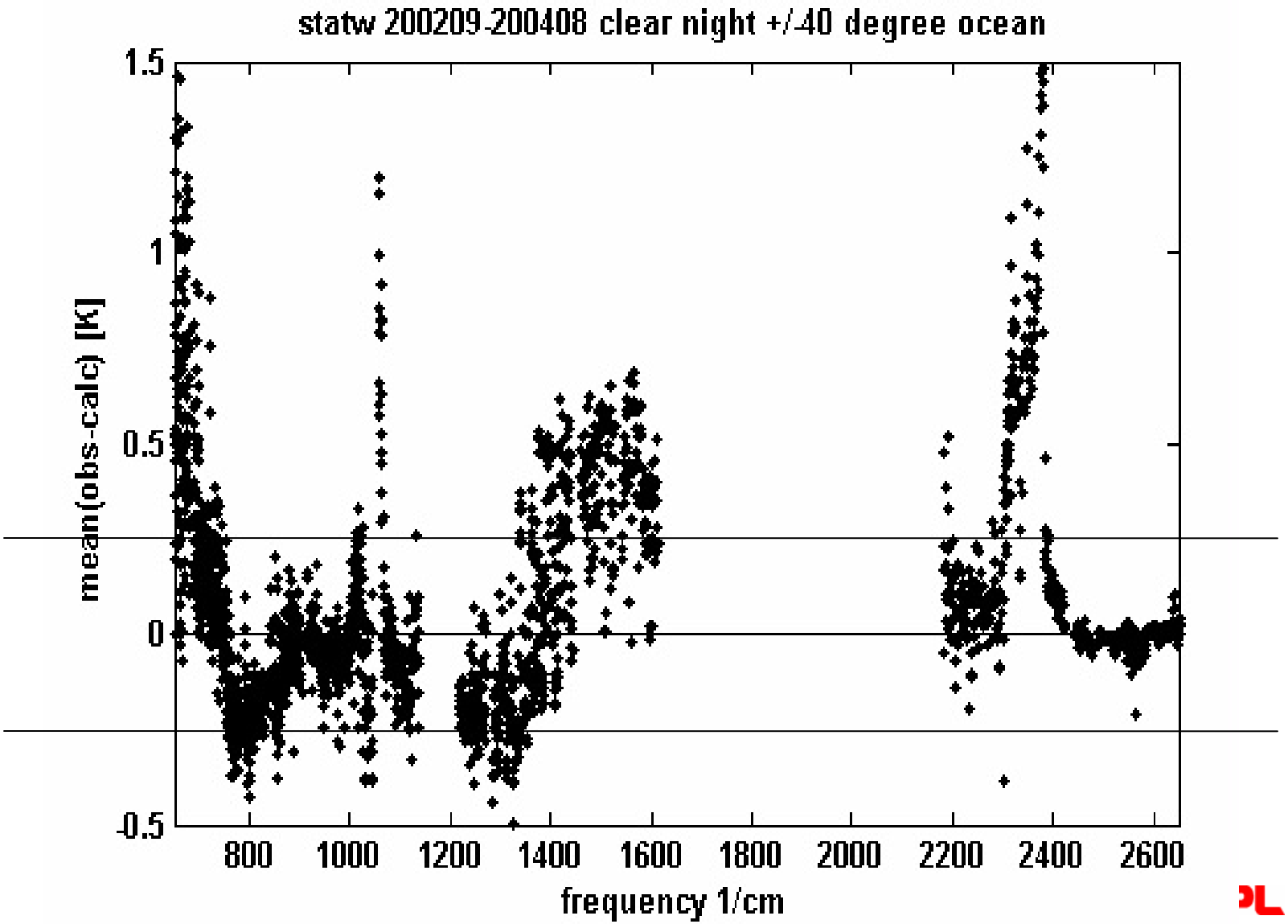
The January 2003 RTA was not tuned to AIRS on-orbit observations

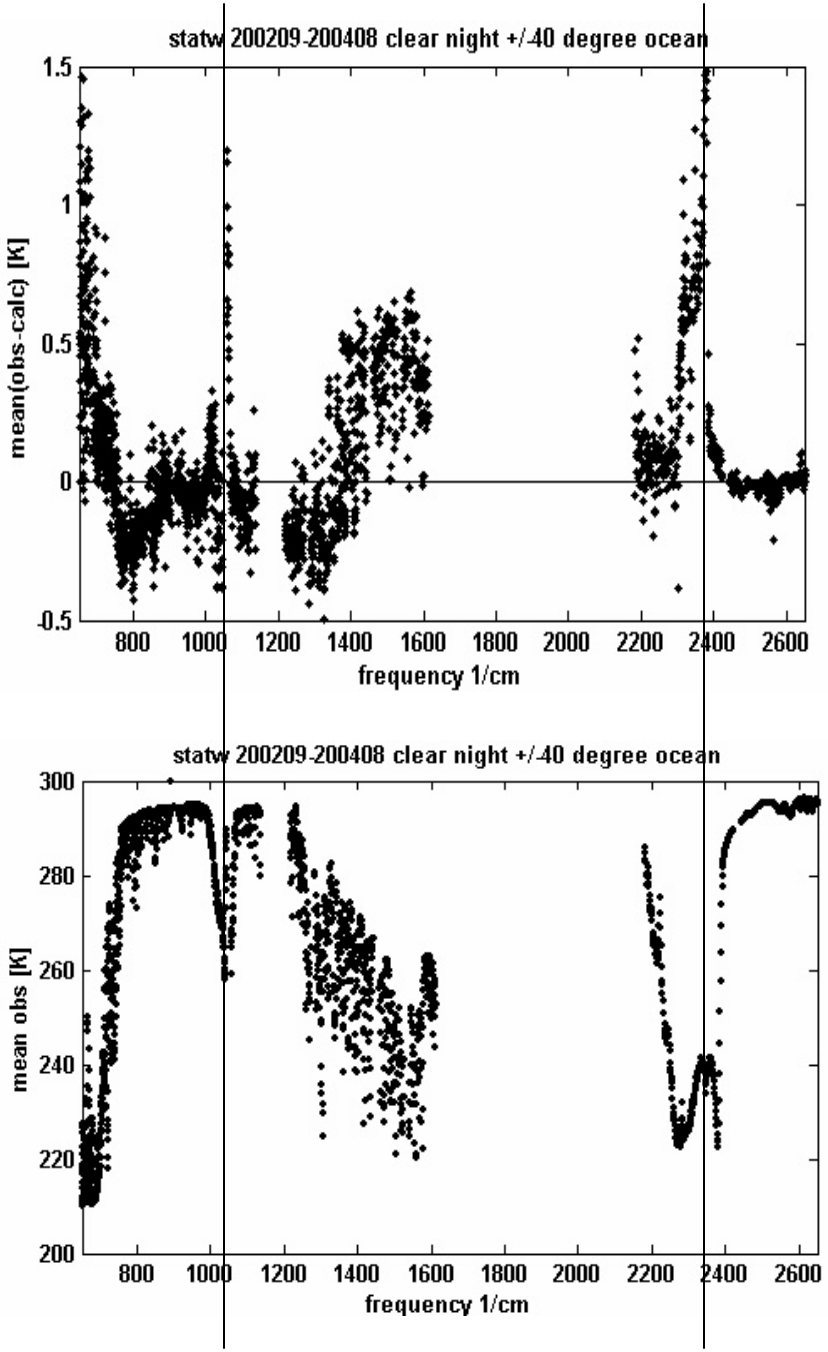
(obs-calc) using two years of data makes sense only if the instrument is regionally and globally stable on this time scale. We have already demonstrated this using the sst2616-rtgsst.

Two year mean tropical night ocean spectrum.
Each spectrum is tied to Tsurf from AIRS at 2616 cm-1



For 2253 of the 2388 channels (obs-calc)=0.06+/-0.28 [K]
(excluded NeDT>1K) min=-1.3 max=1.5 K





The patterns in the bias suggest the larger values are due to calc, not obs.

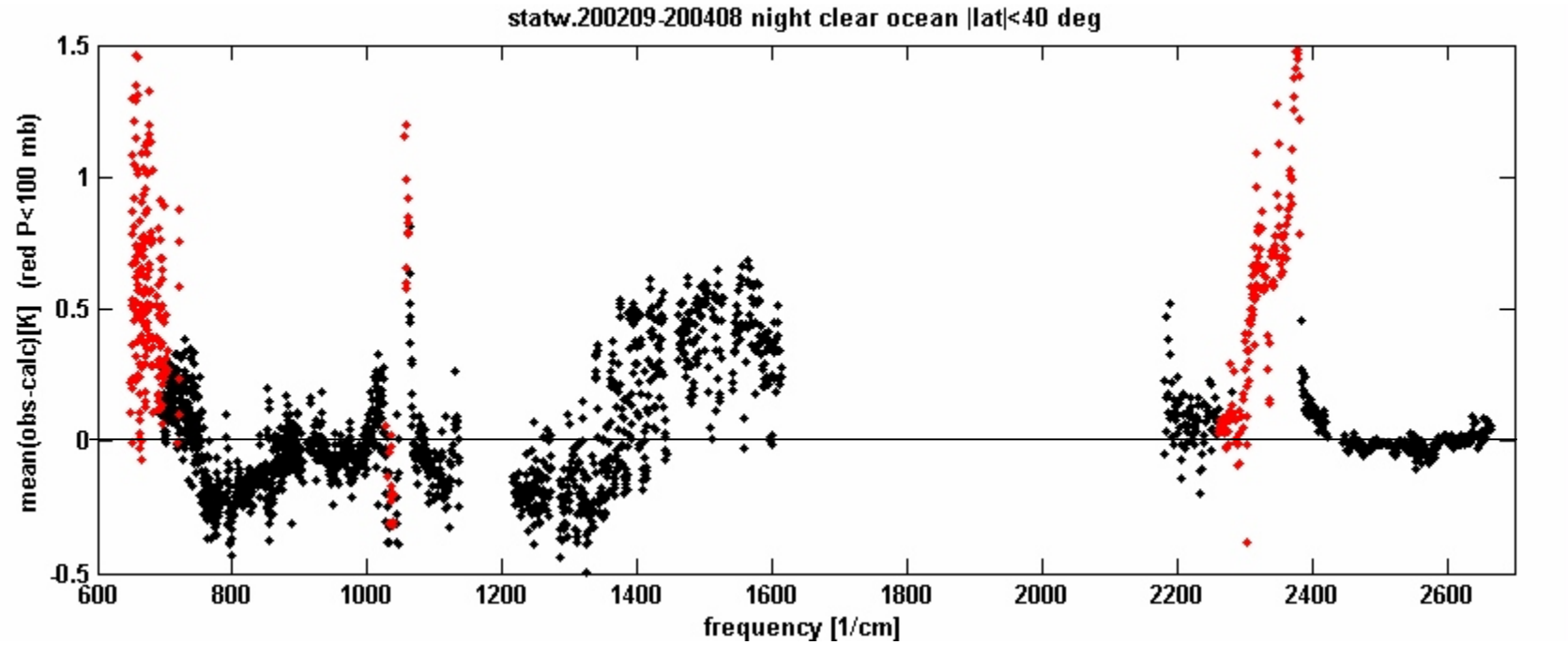
The ECMWF temperature, Ozone and water are suspect above 200 mbar.

The less water sensitivity the lower the bias in windows

AIRS has more water vapor in the lower troposphere, more in the upper troposphere. than ECMWF (due to AMSU assimilation?)

The stratosphere is 1.5 K warmer than ECMWF at 4 microns and 15 microns

Remove all channels above 100 mb from the bias evaluation of (obs-calc)



(obs-calc)= -0.0188 stdev= 0.2028 K 1903 pts
min=-1.083 max= 0.816

The AIRS calibration is good to 200 mK for channels between the surface and 100 mb. This is consistent with the SHIS November 2002 result from 70 mb altitude.

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With better than 200 mK absolute accuracy and better than 10 mK/year stability AIRS has established the benchmark for infrared hyperspectral measurement.

Absolute accuracy is very important, but stability is critical for climate applications.

Residual cloud contamination can result in the wrong interpretation of trends.

Conclusions (continued)

The validated high accuracy of the AIRS data

allows the analysis of (obs-calc) to be used to critique the state of art of the NPW models.

allows the cross-calibration of other infrared sensors

Conclusions (continued)

Climate quality has to be part of the instrument design and prelaunch testing

- Minimize moving parts in the calibration path
- Thermostat the calibration source and the optical bench
- Design for calibration insensitivity to misalignment
- Test pre-launch to cover the likely on-orbit conditions.

AIRS was designed, implemented and tested to meet NASA's requirements for climate quality data.

Four years of data validate the AIRS design approach

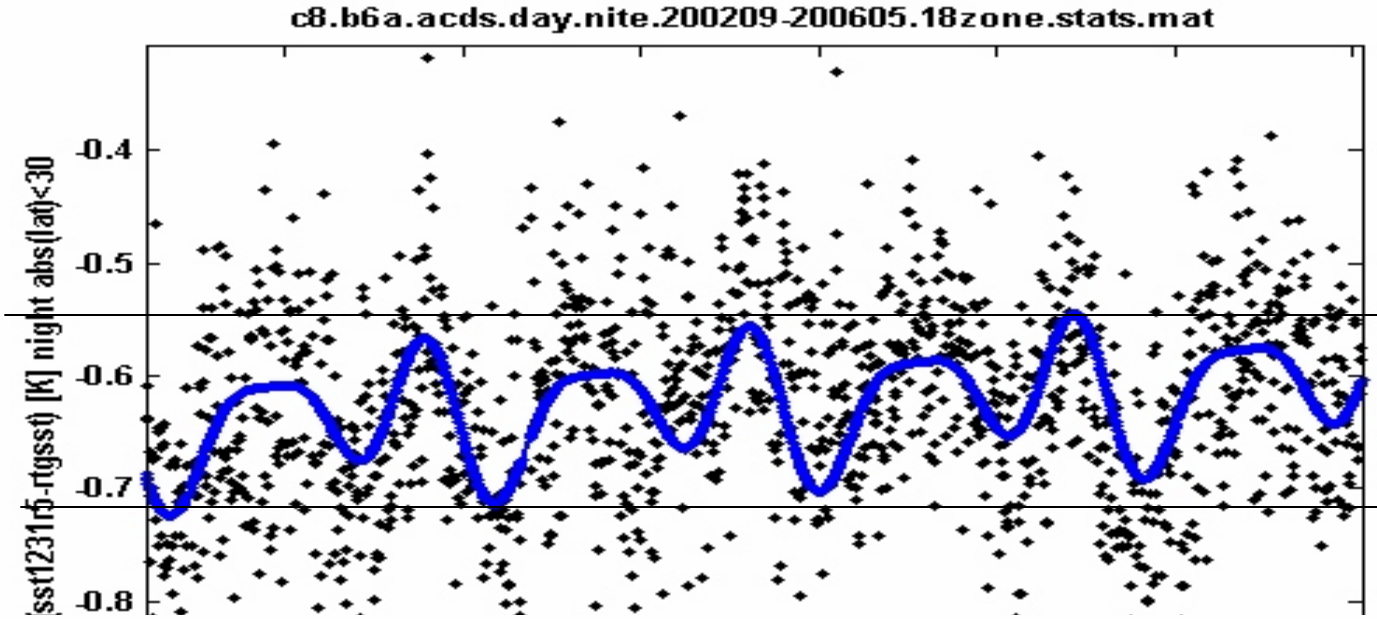
Thank you for our attention.

The AIRS data are freely available from the DAAC at GSFC

To learn more about AIRS visit http://www.jpl.nasa.gov/airs

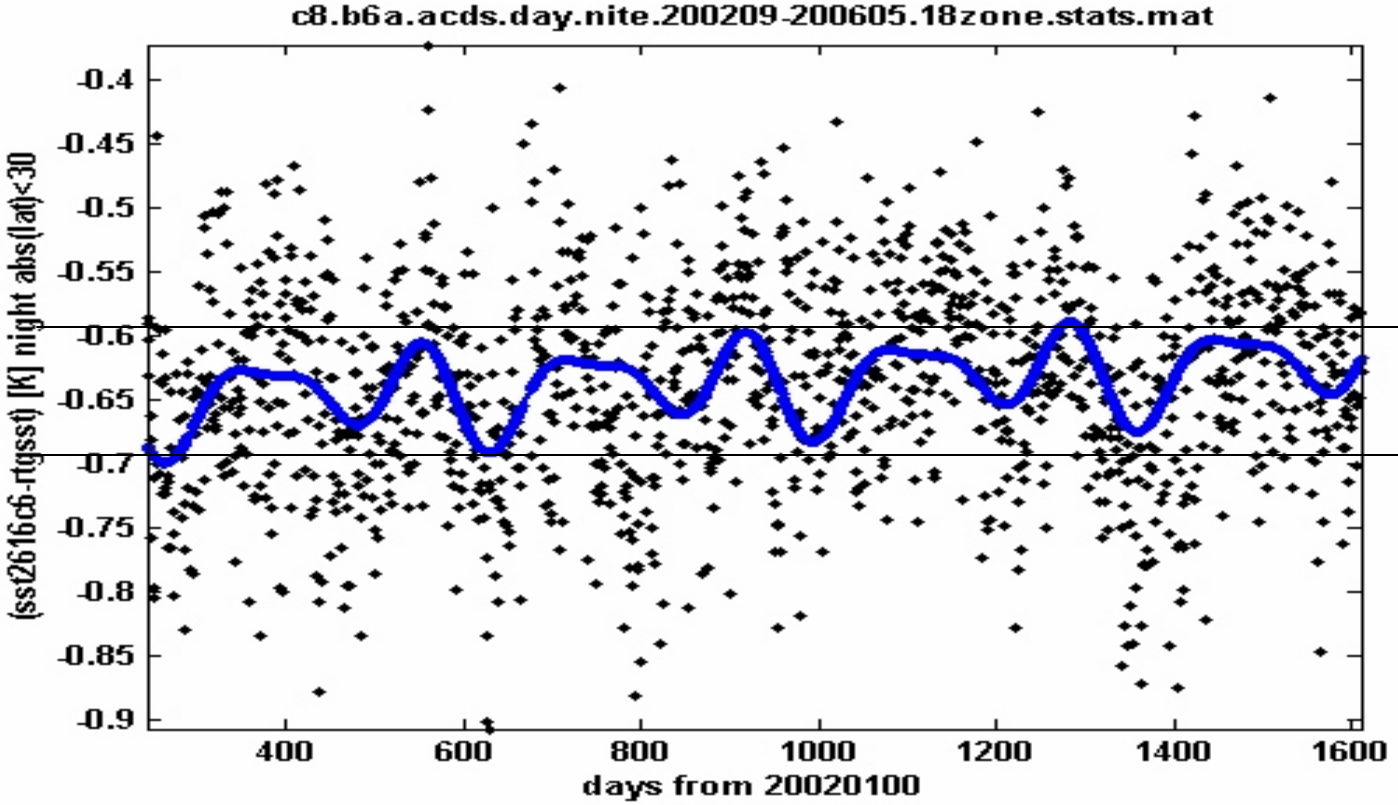
NASA

NASA



The p-p seasonal modulation is bigger with sst1231

0.15 K



0.1 K

Temperature measured by the ocean buoys, presented on a daily grid by the RTGSST. The mean accuracy is NIST traceable at the better than 0.1K level.

For the absolute calibration we use night data only.
For trends we use day and night data.

Use (obs-calc) for the special case of a good window channel
i.e. we compare the observed radiance with the radiance expected based on the RTGSST corrected for atmospheric conditions and emissivity.

We expect a relatively stable 400 mK cold bias at night due to the combination of the skin/buoy bias and the RTGSST night bias.
This procedure is equivalent to calculating an sst with AIRS and comparing it to the RTGSST.

We use the 2616 cm-1 channel, which has on average only 0.2K of atmospheric absorption due to water vapor.

The 2616 cm-1 channel is correct for water vapor using the depth of the 2607 cm-1 water sensitive channels